Report as of FY2008 for 2008AL70B: "Estimating Regional and Local Scale Surface Moisture as an Indicator of Drought and Crop Yield Using Thermal IR Remote Sensing"

Publications

- Conference Proceedings:
  - Kreps, T., L. Marzen. 2008 Estimating Regional Moisture in the Southeast with MODIS Date. Applied Geography Conference. Wilmingron, DE. October.
  - Kreps, T., L. Marzen. 2007 Estimating Regional and Local Scale Surface Moisture as an Indicator of Drought Using Thermal IR Remote Sensing. 4th Annual GIS Symposium and Workshop. Troy, AL.
  - Kreps, T., L. Marzen. 2009. Crop Yeild Response to Drought in Alabama. State of Our Watershed Conference. Alexander City, AL. May

Report Follows

Project Report for Water Resources Research Institute Program under Section 104, Water Resources Research Act of 1984 to the Alabama Water Resources Research Institute

in support of the
Research Project

ESTIMATING REGIONAL AND LOCAL SCALE SURFACE MOISTURE AS AN INDICATOR OF DROUGHT AND CROP YIELD USING THERMAL IR REMOTE SENSING

by

Luke J. Marzen, Ph.D.
Principal Investigator
Auburn University, AL 36849

Diane Hite, Ph.D
Co-Principal Investigator
Auburn University, AL 36849

Wubishet Tadesse, Assistant Professor
Co-Principal Investigator
Alabama A&M University, Normal, AL 35762

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a. Statement of the problem and research objectives

Conventional measures of estimating drought (i.e. Palmer Drought Severity Index, Crop Moisture Index, or Standard Precipitation Index) are calculated from weather station data and thus are limited to relatively few point observations. Remote sensing can provide observations where few previously existed with point data (Legates, 2000). Currently, the most commonly used method to assess drought conditions using satellite imagery is through the use of the Normalized Difference Vegetation Index (NDVI) (Anyamba et al. 2005, Kogan 2005, Cihlar 1997). In 2004, our research group had a project funded by this program to investigate the relationship between NDVI and Thermal IR derived Land Surface Temperature (LST) as previous studies indicated that the relationship between the normalized difference vegetation index (NDVI) and land surface temperature (LST) may provide a better method to effectively assess moisture conditions at the regional scale (Nemani 1993, Kondoh, A., and Y. Oyomada. 2000). The results from that study which investigated the growing seasons from 2000-2003 confirmed that the ratio of NDVI/LST did perform substantially better than NDVI. Even more promising was that LST itself, when compared to traditional ground based measures, performed better than the ratio between NDVI and LST. In September 2006 Dr. Marzen presented research that was a result of this initial funding at a USGS Conference entitled “Managing Drought and Water Scarcity in Vulnerable Environments: Creating a Roadmap for Change in the United States” in Longmont, CO” (Marzen et al. 2006). The conference brought together over 200 academics, resource managers, and GIS professionals to formulate a strategy to handle future water scarcity issues. In panel discussions it was determined that the ability to better monitor and detect drought is essential to sustainability of water resources and that Thermal IR remote sensing appears to be the most promising technology. Most of the discussion centered on water scarcity in the West but as Dr. Marzen in discussions pointed out even the normally humid southeast has been devastated by drought in recent years.

In preliminary investigations at the climate division level, remote sensing methods were evaluated to estimate surface moisture conditions using MODIS vegetation indices and temperature products (Marzen et al. 2006, Marzen et al. 2003). In these studies the ratio of NDVI/LST, NDVI, and LST using MODIS data were compared to CMI and PDSI for estimating surface moisture and associated drought conditions. Our initial results indicate that LST performed the best in mapping moisture conditions in the humid southeast over our limited 3-year time study. This research continued the monitoring and evaluation by looking at 2003-2005 data in the southeast and also a 2000-2005 comparison in a semi-arid western US study area. In the continuation of this study we also propose to compare NDVI and LST to crop yields for a chapter in Ms. Tyler Kreps’ (GRA in Agricultural Economics) Masters thesis that is being directed by Dr. Hite and Dr. Marzen.

Initial investigations have led us to hypothesize that LST performs better in humid climates than NDVI for estimating surface moisture conditions than in semi-arid climates. More observations using carefully selected time periods during known periods of drought variation in the humid southeast and semi-arid west will provide a better understanding and assessment of the ability to use remotely sensed satellite

measurements as a potential indication of drought. These data as promised in our initial funded proposal are being shared for the state of Alabama on the AlabamaView website at http://www.alabamaview.org/modis.htm. Our results show that LST perform the best at estimating surface moisture conditions in comparisons with ground-based observations. Our regional scale MODIS satellite observations and analysis will be continued but we will also look at more localized imagery with Landsat TM derived LST from the thermal bands at a 30m pixel spatial resolution. Finally, we looked at a methodology to test the use of thermal remote sensing as an indicator of crop yield.

The overall goal of this proposed project is continue to evaluate and validate methods to use remotely sensed data to estimate surface moisture conditions as an indication of drought and associated economic impacts on crop yield. This information will ideally provide improved forecasting and prediction of drought conditions and will be useful to resource managers to monitor the need for water which will be increasingly important as water resources become scarcer. The following objectives and tasks were completed:

1. Collection of MODIS LST and NDVI data for 2000 to 2005 for the southeastern and western United States study areas and compare these data to corresponding Crop Moisture Index data in both study areas.
2. Collection of cloud-free Landsat TM data from the AlabamaView website and produce LST derived from the thermal bands. We have since expanded this study into another project funded by the Multi-state Hatch program for a thesis project estimating Evapotranspiration in Wolf Bay.
3. For objective 3 we tried to compare LST averages to crop yields for a chapter in Ms. Tyler Kreps Master's thesis on the remote sensing of drought but the National Agricultural Statistics Survey (NASS) was not complete. Therefore we are using NASS data and traditional ground measurements to estimate direct impacts of temperature, precipitation, radiation, wind speed, and humidity on county level crop yield. Ms. Kreps is finishing these models this summer in the completion of her Master's thesis.
4. We continue to share NDVI and LST products produced by the graduate student with user communities on the AlabamaView website (http://www.alabamaview.org/modis.htm) in a timely manner.
5. Provided undergraduate and graduate level training in the use of remote sensing and GIS for hydro-climatology and remote sensing research to M.S. candidates Tyler Kreps (Ag Econ), Nishan Bhattarai (Forestry); undergraduate students Davis Fite, Nathan Pauley, Patrick Barrineau, Chandler White, and Jason McGinniss. Funds were leveraged from AlabamaView to pay undergraduates to work on the project.
6. Assist undergraduate and graduate students in preparing paper/poster presentations of the results of the study at the 2007 and 2008 Alabama Water Resource Conferences. Listed in

b. Methods

For this study, MOD11 (land surface temperatures and emissivity) and MOD13 (vegetation indices) data products were used corresponding to weather station observations for 2 week periods in the growing seasons (April-October) of 2000 – 2005. MOD11 provides. LST and NDVI values were compared to conventional ground based drought index values that are calculated from weather stations that are located within regional climate divisions. The Crop Moisture Index (CMI) and Palmer Drought Severity Index (PDSI) will be collected at the climate division level for the two study areas. The southeastern study area includes Alabama, Georgia, Florida, South Carolina, North Carolina, and Virginia. The western study area likely will include Wyoming, South Dakota, Nebraska, Kansas, and Oklahoma.

The localized study used the thermal bands from Landsat TM data. These data are processed for geometric and radiometric corrections by the USGS Eros Data Center and are made available for download free at the AlabamaView website.

For the 2008 project we continued the analysis described above and added an economic aspect to the study. We used crop data as reported by the USDA on a county level basis by row crop (http://www.nass.usda.gov/Data_and_Statistics/) to ground based measurements of temperature, precipitation, radiation, wind speed, and humidity.

c. Principal Findings

LST continued to perform the strongest in terms of estimating surface moisture and associated drought conditions when compared to CMI. Table 1 shows correlation results (2000 through 2005) for the southeastern study. Through the economic aspect of the study we have found that it is difficult to rely on NASS data because the data are incomplete and the crop yield data reported through the survey methods do not consider management decisions (such as irrigated vs. non-irrigated land, fertilizer or herbicide application, and in-crop variation). We believe that there is potential for using satellite and aerial imagery for estimating crop yield but it is difficult to validate at a regional scale. If local scale studies (within field) can be conducted then there may be some arguments to be made that it is justified to apply the Remote Sensing methods to regional scales. The local scale study is now the focus of Nishan Bhattarai Master's thesis which we are leveraging funds from another project to keep this research going. Preliminary results of the economic study reveal that crop yield is substantially influenced by the temperature, precipitation, radiation, wind speed, and humidity. Ms. Kreps will complete this aspect of the study and defend her thesis by July 10th.

Table 1 Pearson's Correlation Coefficients for LST and CMI for growing seasons of each Climate Division

CLIMATE DIVISION	2000	2001	2002	2003	2004	2005
APPALACHIAN MOUNTAIN	-0.67	-0.32	-0.41	-0.47	0.154	-0.73
NORTHERN VALLEY	-0.72	-0.19	-0.58	-0.41	-0.02	-0.67
EASTERN VALLEY	-0.75	-0.51	-0.44	-0.36	6E-04	-0.65
UPPER PLAINS	-0.72	-0.3	-0.41	-0.42	-0.06	-0.5
PIEDMONT PLATEAU	-0.59	-0.66	-0.52	-0.38	0.091	-0.55
PRAIRIE	-0.62	-0.65	-0.55	-0.43	-0.05	-0.52
COASTAL PLAIN	-0.58	-0.58	-0.29	-0.49	0.28	-0.33
GULF	-0.53	-0.25	0.08	-0.05	0.27	-0.48

d. Presentations/published abstracts

Kreps, T., L.Marzen. 2009. Crop Yield Response to Drought in Alabama. State of our Watershed Conference. Alexander City, AL. May.

Kreps, T., L.Marzen. 2008. Estimating Surface Moisture with Remote Sensing as an Indicator of Drought in the Southeast US. Alabama Water Resources Conference. Orange Beach, AL, September.

Kreps, T., L.Marzen. 2008. Estimating Regional Scale Surface Moisture in the Southeast with MODIS Data. Applied Geography Conference. Wilmington, DE. October.

Kreps T. and L.J. Marzen. 2007. Estimating Regional and Local Scale Surface Moisture and an Indicator of Drought Using Thermal IR Remote Sensing. 4th Annual GIS Symposium and Workshop. Troy, AL. (50%)

Kreps, T. and L,J. Marzen. 2007. Estimating Regional Scale Surface Moisture in the Southeast with MODIS Data. Alabama Water Resources Conference. Orange Beach, AL (50%)

e. Students

M.S. candidates Tyler Kreps (Ag Econ), Nishan Bhattarai (Forestry); undergraduate students Davis Fite, Nathan Pauley, Patrick Barrineau, Chandler White, and Jason McGinniss